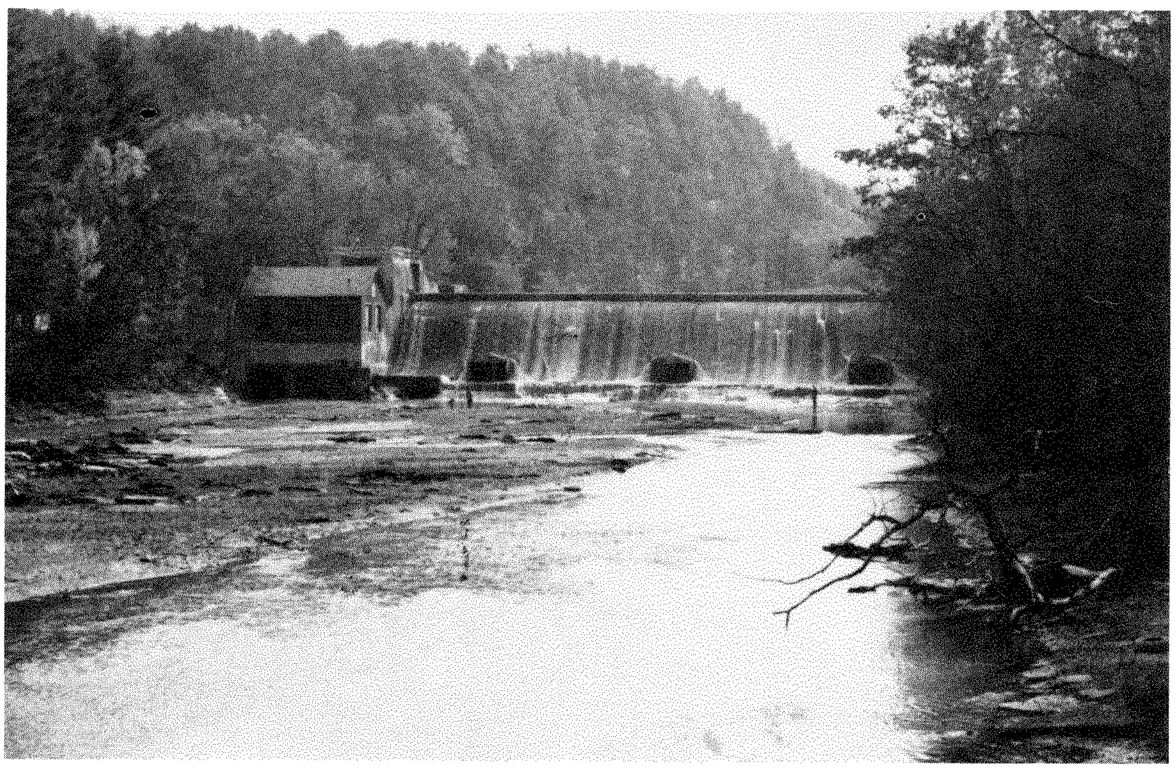


CATTARAUGUS CREEK AT SPRINGVILLE DAM DOWNSTREAM OF THE WVDP

4.0 Radiological Dose Assessment

4.1 Introduction

Each year the potential radiological dose to the public is assessed in order to ensure that no individual could possibly have received an exposure which exceeded the limits established by the cognizant regulatory agencies. The results of these conservative calculations demonstrate that the hypothetical maximum dose to an off-site resident is well below permissible standards and is consistent with effective applications of the "as low as reasonably achievable" (ALARA) philosophy of radiation protection.

Dose Estimates

This chapter describes the methods used to estimate the dose to the public from radionuclides emitted from the West Valley Demonstration Project through air and water discharges during 1989. The dose estimates are based on concentrations of radionuclides measured in air, water, and in food samples collected both on– and off–site throughout 1989. These estimates are compared to the radiation standards established by the Department of Energy and the Environmental Protection Agency for protection of the public. The radiation doses reported for 1989 are also compared to the doses reported in previous years.

Computer Modeling

Because of the difficulty of measuring the small amounts of radionuclides emitted from the site beyond those that occur naturally in the environment, computer models were used to calculate the environmental dispersion of the radionuclides emitted from monitored ventilation stacks and liquid discharge points on the site. These models have been approved by the Department of Energy and the Environmental Protection Agency to demonstrate compliance with radiation standards. Radiological dose is evaluated for the three major exposure pathways: external irradiation, inhalation, and ingestion of local food products. The dose contributions from each radionuclide and pathway combination are then summed to obtain the reported dose estimates.

In addition to the computer estimates, concentrations of radionuclides in air and food samples collected near the site are compared to background concentrations. In those samples where radionuclides were determined to be in excess of background concentrations, the excess was attributed to Project releases. In such cases, estimates were made of the maximum radiation dose that could be incurred by a nearby resident.

4.1.1 Sources of Radiation Energy and Radiation Exposure

Radionuclides

Atoms that emit radiation are called radionuclides. Radionuclides are variations – isotopes – of elements: They have the same number of protons and electrons but different numbers of neutrons, resulting in different atomic masses. For example, the element hydrogen has two stable isotopes, H-1 and H-2 (deuterium), and one radioactive isotope, H-3 (tritium). (The numbers following the element's symbol identify the atomic mass, the numbers of protons and neutrons, in the nucleus).

Once a radioactive atom decays by emitting radiation, the resulting daughter atom may itself be radioactive or stable. Each radioactive isotope has a unique half-life which represents the time it takes for 50% of the atoms to decay. Strontium-90 and cesium-137 have half-lives of about 30 years, while plutonium-239 has a 24,000 year half-life.

Radiation Dose

The energy released from a radionuclide is eventually deposited in matter encountered along the path of radiation, resulting in a radiation dose to the absorbing material. The absorbing material can be either inanimate matter or living tissue.

While most of the radiation dose affecting the general public is background radiation, manmade sources of radiation may also contribute to the radiation dose of individual members of the public. Such sources include diagnostic and therapeutic x-rays, nuclear medicine, consumer products such as smoke detectors and cigarettes, fallout from atmospheric nuclear weapons tests, and effluents from nuclear fuel cycle facilities.

The West Valley Demonstration Project is part of the nuclear fuel cycle. The radionuclides present at the site are left over from the recycling of commercial nuclear fuel during the 1960s and early 1970s. A very small fraction of these radionuclides are released off-site annually through ventilation systems and liquid discharges. An even smaller fraction actually contributes to the radiation dose to the surrounding population.

4.1.2 Health Effects of Low Levels of Radiation

The concept of dose equivalent (DE) was developed by the radiation protection community to allow a rough comparison of doses from different types of radiation.

Effects of Radiation on Body Organs

The primary effect of low levels of radiation in an exposed individual appears to be an increased risk of cancer. Radionuclides entering the body through air, water, or food are usually distributed unevenly in different organs of the body. For example, isotopes of iodine concentrate in the thyroid gland. Strontium, plutonium, and americium isotopes concentrate in the skeleton. Uranium and plutonium isotopes, when inhaled, remain in the lungs for a long time. Some radionuclides such as tritium, carbon-14, or cesium-137, will be distributed uniformly throughout the body. Depending on the radionuclide, some organs may receive quite different doses. Moreover, another complicating factor is that at the same dose levels certain organs (such as the breast) are more prone to developing a fatal cancer than other organs (such as the thyroid).

Estimating Dose Methodology

The International Commission on Radiological Protection (ICRP) found a way to account for this difference in radionuclide distribution and organ sensitivity. In Publications 26 (1977) and 30 (1979), the Commission developed an organ-weighted-average dose methodology to limit permissible worker exposures following intakes of radionuclides. This weighting factor – a ratio of the risk from a dose to a specific organ or tissue to the total risk when the whole body is uniformly irradiated – represents the relative sensitivity of a particular organ to develop a fatal effect. For example, to determine the weighting factor following a uniform irradiation, the risk factor of death from cancer of a specific organ is divided by the total risk of dying from cancer of any organ.

Units of Measurement

The unit of dose equivalent measurement(DE) is the rem. The international unit of measurement of DE (and of the effective dose equivalent, EDE) is the sievert (Sv), which is equal to 100 rem. The millisievert (mSv), one thousand times lower, is used more frequently to report the low DEs encountered in environmental exposures. To obtain the *effective dose equivalent*, which is an estimate of the total risk from radiation exposure, the organ doses (dose equivalents) are multiplied by the respective weighting factor. These weighted DEs are then summed to obtain the effective dose equivalent (EDE).

The National Council on Radiation Protection and Measurements (NCRP) Report 93 (1987) estimates that the average annual effective dose equivalent received by a person living in the U.S. is about 360 mrem (3.6 mSv) from both natural and manmade sources of radiation (See Figure 4-1). This number is based on the collective EDE, defined as the total EDE received by a population (expressed in units of person-Sv or person-rem). The average individual EDE is obtained by dividing the collective EDE by the population number.

Risk Estimates

The Committee on Biological Effects of Ionizing Radiations (BEIR) has estimated that the increased risk of dying from cancer from a single acute dose of 10 rem (0.1 Sv) is about 0.8% of the background risk of cancer. According to the Committee, chronic exposure, i.e., accumulation of the same dose over long periods of time, might, compared to acute exposure, reduce the risk by a factor of two or more. The death rate from cancer from all causes in the United States is currently about one in eight.

The BEIR Committee has stressed that the health effects of very low levels of radiation are not clear, and any use of risk estimates at these levels is subject to great uncertainty (BEIR, 1990). As will be shown in the following sections, the estimated maximum effective dose equivalent received by a member of the public from Project activities during 1989 is many orders of magnitude lower than the exposures considered in the BEIR report.

4.2 Estimated Radiological Dose from Airborne Effluents

Sources of Radioactivity from the WVDP

As reported in Chapter 2, "Effluent and Environmental Monitoring," five stacks and vents were monitored for radioactive air emissions during 1989. The activity that was released to the atmosphere from these stacks and vents is listed in Tables C-2.1 through C-2.11 in Appendix C-2. The main plant stack, which vents to the atmosphere at a height of 60 meters (197 ft), is considered an elevated release; all other releases are considered ground level (10 m) releases. Wind data collected from the on-site meteorological tower during 1989 were used as input to the dose assessment codes. Data collected at the 60 meter and 10 meter heights were used in combination with elevated and ground level effluent release data respectively. (See Figures 4-2 and 4-3).

Airborne emissions of radionuclides are regulated by the EPA under the Clean Air Act. Department of Energy facilities are subject to 40 CFR 61, subpart H, "National Emission Standards for Hazardous Air Pollutants (NESHAP) - Radionuclides." The applicable standard for radionuclides released during 1989 is 25 mrem (0.25 mSv) and 75 mrem (0.75 mSv) to the whole body and any organ, respectively, for any member of the public.

The Clean Air Act Code (CAAC) is the approved version of the AIRDOS-EPA computer code used to demonstrate compliance with the standard for the 1989 assessment period. Using site-specific meteorological data, AIRDOS-EPA (Moore et al., 1979) calculates the dispersion of radionuclides into the environment following airborne releases and then estimates the external dose to individuals from radionuclides both in the air and deposited on the ground. It also estimates the doses to individuals from inhalation of contaminated air and ingestion of contaminated water and foods produced near the site. The mainframe computer versions of AIRDOS-EPA can also be used to estimate the collective dose to the population residing within 80 km of the site.

4.2.1 Maximum Dose to an Off-Site Resident

Based on the airborne radioactivity released from the site during 1989, and using the CAAC, a person living in the vicinity of the WVDP was estimated to receive a whole body dose equivalent of 0.0046 mrem (0.000046 mSv). This maximally exposed individual was assumed to reside continuously about 1.9 km north-northwest from the site, eating locally produced foods at the maximum consumption rates for an adult. Almost 98% of the dose was contributed by iodine-129, primarily from ingestion; the remaining radionuclides contributed less than 1% each to the total dose.

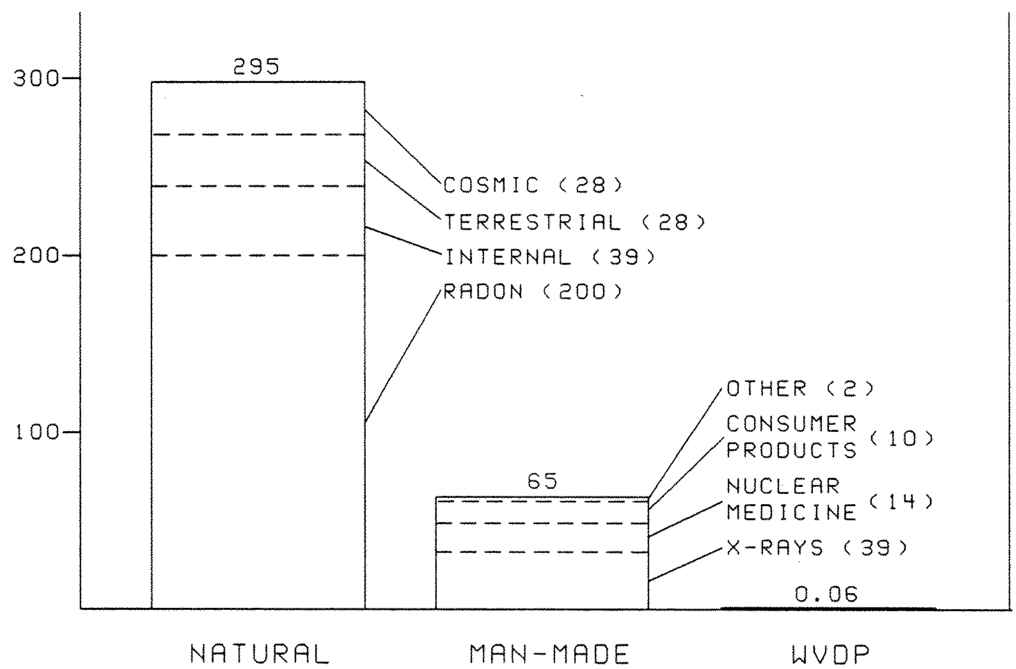
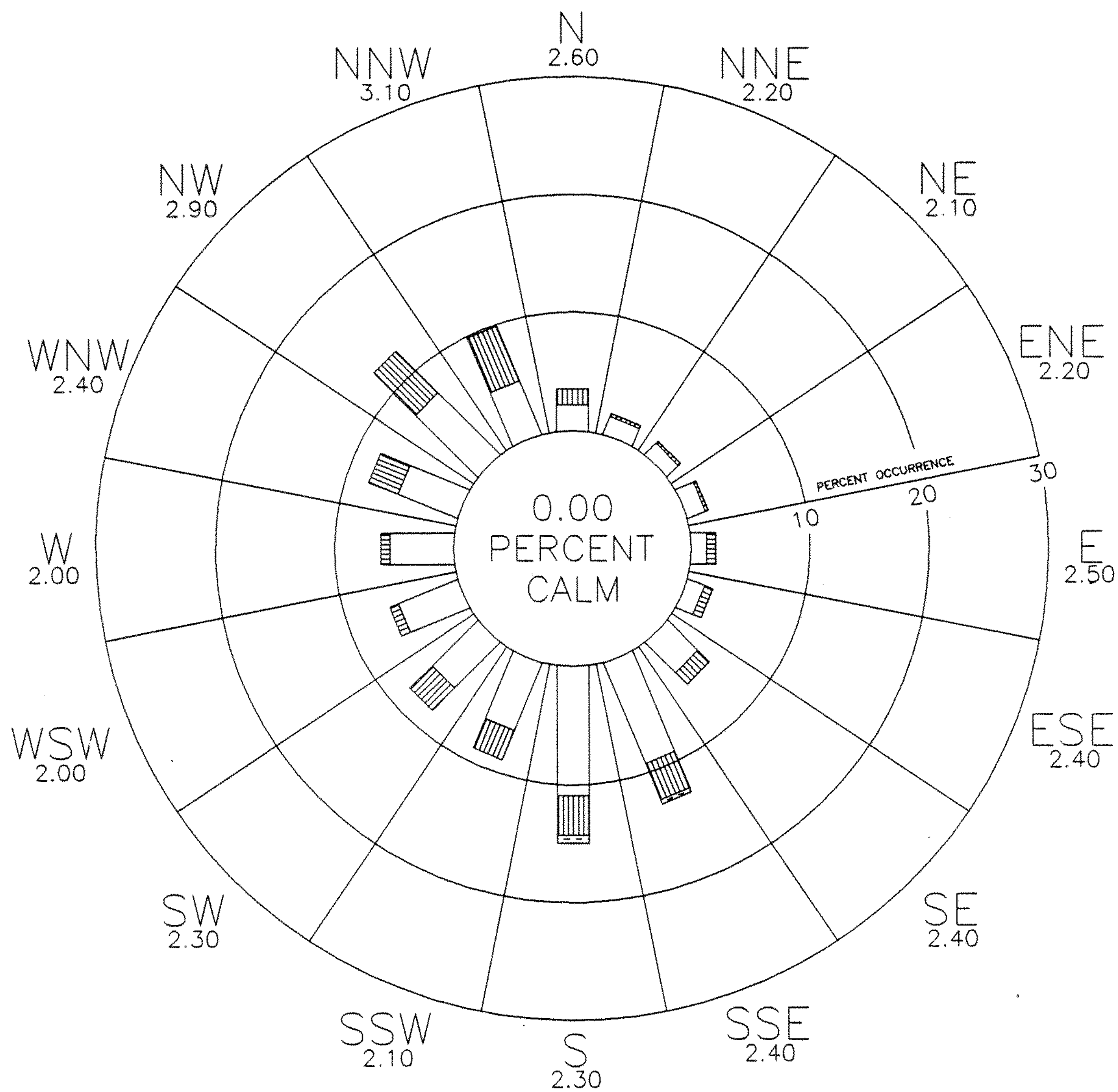


Figure 4-1

Comparison of annual radiation doses in millirem to an average member of the U.S. population (NCRP, 1987) with the maximum dose to an off-site resident from 1989 WVDP effluents.



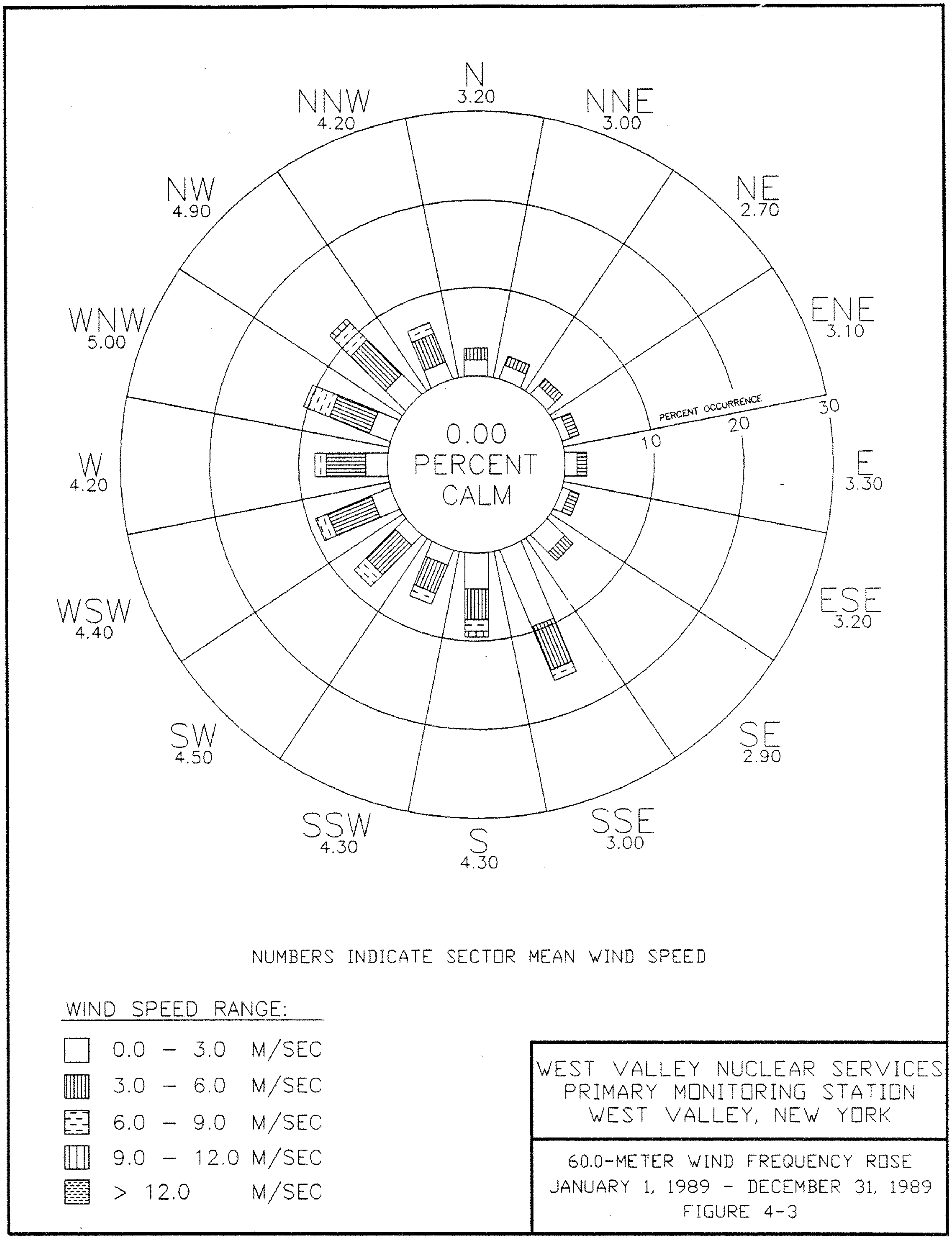
NUMBERS INDICATE SECTOR MEAN WIND SPEED

WIND SPEED RANGE:

- 0.0 – 3.0 M/SEC
- 3.0 – 6.0 M/SEC
- 6.0 – 9.0 M/SEC
- 9.0 – 12.0 M/SEC
- > 12.0 M/SEC

WEST VALLEY NUCLEAR SERVICES
PRIMARY MONITORING STATION
WEST VALLEY, NEW YORK

10.0-METER WIND FREQUENCY ROSE
JANUARY 1, 1989 - DECEMBER 31, 1989
FIGURE 4-2



WEST VALLEY NUCLEAR SERVICES
PRIMARY MONITORING STATION
WEST VALLEY, NEW YORK

60.0-METER WIND FREQUENCY ROSE
JANUARY 1, 1989 – DECEMBER 31, 1989
FIGURE 4-3

The dose reported above is 0.018% of the 25 mrem (0.25 mSv) standard and can be compared to about eight minutes of the annual background radiation received by an average member of the U.S. population.

4.2.2 Maximum Organ Dose

As a result of radioactivity in airborne emissions from the site during 1989, the maximally exposed off-site individual incurred an estimated dose equivalent of 0.046 mrem (0.00046 mSv) to the thyroid, the organ receiving the highest dose. Almost all of the dose was contributed by iodine-129. This dose is 0.061% of the 75 mrem (0.75 mSv) standard.

4. 2. 3 Revised National Emission Standards for Hazardous Air Pollutants (NESHAP) for 1990

Effective December 15, 1989, the EPA promulgated a revised standard of 10 mrem (0.1 mSv) effective dose equivalent (EDE) to any member of the public, replacing the 25 mrem (0.25 mSv) whole body dose equivalent standard. The organ dose standard will no longer be effective. While the revised standard is not applicable to the current reporting period, a dose assessment was performed using the new methodology incorporated in the revised NESHAP to facilitate the transition to the new standard. Both AIRDOS-PC (Version 3.0, 1989), an EPA-approved personal computer version of AIRDOS-EPA, and CAP-88, the EPA-approved replacement for CAAC, were used to estimate the dose to the maximally exposed off-site resident. Using 1989 meteorological and effluent data, an effective dose equivalent of 0.00073 mrem (0.0000073 mSv) was calculated using AIRDOS-PC and an EDE of 0.00023 mrem (0.0000023 mSv) was calculated using CAP-88. These doses are 0.0023% to 0.0073 % (for CAP-88 and AIRDOS-PC, respectively) of the revised standard and lower than the whole body dose calculated with CAAC by about a factor of ten. Most of the difference in calculated doses stems from the use of revised organ dose weighting factors and food consumption rates in the new codes. Because most of the dose is from iodine-129, a reduction in the thyroid weighting factor of about three reduces the EDE by a factor of three. The newer codes also incorporate average food consumption rates that are only one-third the maximum rates used in the CAAC. This results in another reduction by a factor of three in the EDE.

4.2.4 Collective Dose to the Population

The CAP-88 version (replacing the CAAC version) of AIRDOS-EPA was used to estimate the collective dose to the population. According to census projections, an estimated 1.7 million people reside within 80 km (50 miles)of the WVDP. This population received an estimated 0.0069 person-rem (0.000069 person-Sv) collective EDE from radioactive airborne effluents released from the WVDP during 1989. The resulting average EDE per individual is 0.0000041 mrem (0.000000041 mSv).

There are no regulations limiting collective doses to the population. However, the calculated average individual dose is 73 million times lower than (or an exposure less than one second of) the 300 mrem (3 mSv) that an average member of the U.S. population receives in one year from natural background radiation.

4.3 Estimated Radiological Dose from Liquid Effluents

As reported in Chapter 2, four batch releases of liquid radioactive effluents were monitored during 1989. The radioactivity that was discharged in these effluents is listed in Appendix C-1, Table C-1.1.

Dose Calculations

The computer code LADTAP II (Simpson and McGill, 1980) was used to calculate the dose to the maximally exposed off-site individual and the collective dose to the population from routine releases and dispersion of these effluents. Since the effluents eventually reach Cattaraugus Creek, which is not used as a source of drinking water, the local exposure pathway calculated by the code is from the consumption of 21 kg (46 lb) of fish caught in the creek. Population dose estimates assume that the radionuclides are further diluted in Lake Erie before reaching municipal drinking water supplies. A detailed description of LADTAP II is given in Yuan and Dooley, 1987.

Currently there are no EPA standards establishing limits on the radiation dose to members of the public from liquid effluents except as applied in the 40 CFR 141 and 40 CFR 143 Drinking Water Guidelines (USEPA 1984b,c). The potable water wells sampled for radionuclides are upgradient of the

West Valley Demonstration Project and are not considered a realistic pathway in the dose assessment. Since Cattaraugus Creek is not designated as a drinking water supply, the radiation dose estimated using LADTAP II was compared with the limits stated in DOE Order 5400.5.

4. 3. 1 Maximum Dose to an Off-Site Individual

Based on the radioactivity in liquid effluents released from the WVDP during 1989, an off-site individual was estimated to receive a maximum effective dose equivalent (EDE) of 0.051 mrem (0.00051 mSv). Approximately two-thirds of this dose is from cesium-137; the remainder comes from strontium-90 and carbon-14. This dose is about 6000 times lower than the 300 mrem (3 mSv) that an average member of the U.S. population receives in one year from natural background radiation – or an exposure of one and one-half hour.

No maximum organ dose was computed, as LADTAP II employs the risk-based methodology currently recommended by the ICRP rather than the critical organ methodology of the older International Commission on Radiological Protection (ICRP) guidance.

4. 3. 2 Collective Dose to the Population

As a result of radioactivity released in liquid effluents from the WVDP during 1989, the population living within 80 km (50 miles)of the site received a collective effective dose equivalent of 0.057 person-rem (0.00057 person-Sv). This estimate is based on a population of 1.7 million living within the 80 km radius. The resulting average effective dose equivalent per individual is 0.000034 mrem (0.000000034 mSv), or approximately 9 million times lower than the 300 mrem (3 mSv)that an average person receives in one year from natural background radiation – or an exposure of less than four seconds.

Although the collective dose from liquid effluents was twice as high in 1989 when compared to the previous year's estimate, a comparison of dose estimates from the past four years indicates that the general trend is downward.

4.4 Estimated Radiological Dose from All Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project during 1989 is simply the sum of the individual dose contributions. The maximum effective dose equivalent from all pathways to a nearby resident was 0.056 mrem (0.00056 mSv). The total collective effective dose equivalent to the population within 80 km (50 miles) of the site was 0.064 person-rem (0.00064 person-Sv), with an average EDE of 0.000038 mrem (0.00000038 mSv) per individual.

The maximum dose to an individual was 0.056% of the 100 mrem (1 mSv) annual limit in DOE Order 5400.5. Figure 4-4 shows the trend in dose to the maximally exposed individual over the last four years. The contribution from airborne releases increased during 1989, but the total (airborne plus liquid) decreased from last year's estimate.

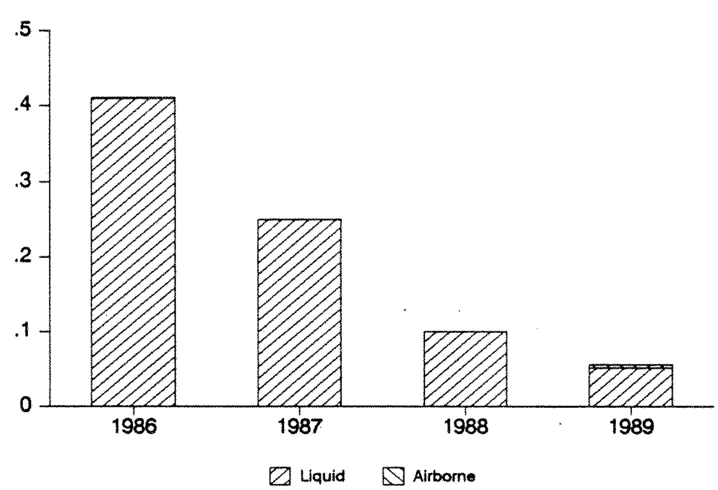


Figure 4-4

Maximum dose equivalent (mrem) from liquid and airborne effluents to an individual residing near the West Valley Demonstration Project.

Table 4-1: Summary of Dose Assessment From 1989 WVDP Effluents

	Maximum Dose to an Individual [1]	*Maximum Dose to the Population* [2]
Dose Equivalent from Airborne Emissions [3]	0.0046/0.046 mrem[4] (0.000046/0.00046 mSv)	0.0069 person-rem (0.000069 person-Sv)
EPA Radiation Protection Standards [5]	25/75 mrem[4]	-o-
(percent of standard)	(0.018%/0.061%)	
Dose Equivalent from Liquid Effluents [6]	0.051 mrem (0.00051 mSv)	0.057 person-rem (0.00057 person-Sv)
Dose Equivalent from All Releases	0.056 mrem (0.00056 mSv)	0.064 person-rem (0.00064 person-Sv)
DOE Radiation Protection Standard [7]	100 mrem	-o-
(percent of DOE standard)	(0.056%)	
Background Effective Dose Equivalent[8]	300 mrem(3 mSv)	510,000 person-rem (5100 person-Sv)
(percent of background)	(0.019%)	(0.000059%)

[1] Maximally exposed individual at a residence 1.9 km NNW from the main plant
[2] Population of 1.7 million within 80 km of the site
[3] Calculated using AIRDOS-EPA (CAAC for individual/CAP-88 for population)
[4] Whole body/maximum organ dose equivalents (collective dose is effective dose equivalent)
[5] Airborne emissions only (changed to 10 mrem EDE for 1990)
[6] Calculated using LADTAP II (effective dose equivalent)
[7] Applies to doses from both airborne and liquid effluents
[8] U.S. Average (Source: NCRP, 1987)

Table 4-1 on the opposing page summarizes the dose contributions from all pathways and compares the individual doses to the applicable standards.

Figure 4-5, the trend in collective dose to the population, shows an increase relative to last year's estimate, but is about the same as the 1987 estimate. These doses are still well below the regulatory limits.

4.5 Estimated Radiological Dose from Local Food Consumption

In addition to dose estimates based on dispersion modeling, the maximum EDE to a nearby resident from consumption of locally produced food was also estimated. Because the estimated doses using the computer models already incorporate the food pathway, the following doses should not be added to doses reported in previous sections but should serve as an additional means to measure the impact of Project operations.

Near-site and control samples of fish, milk, beef, venison, fruit, and vegetables were collected. The samples were analyzed for various radionuclides, including tritium, potassium-40, cobalt-60, strontium-90, iodine-129, cesium-134 and cesium-137. The measured radionuclide concentrations reported in Tables C-3.1 through C-3.4 are the basis for these dose estimates.

With the exception of milk samples, all radionuclide concentrations are reported in terms of the dry sample weight. Prior to any dose calculations the concentration per wet weight was calculated by factoring in the moisture content of the samples.

When statistically significant differences were found between near-site and background sample concentrations, the excess near-site sample concentration was used as a basis for the dose estimate. Most of the measured radionuclides were found to be under the minimum detectable concentration (MDC). When this was the case for both near-site and control samples, the concentrations in both were assumed to be at background levels.

The EDE to a nearby resident from the consumption of foods with radionuclide concentrations found to be above background concentration was estimated. The potential dose was calculated by multiplying the excess concentration by the maximum adult annual consumption rate for each food and the ingestion unit dose factor for the measured radionuclide. The consumption rates are based on site-specific data and recommendations in the NRC Regulatory Guide 1.109 for terrestrial food chain dose assessments (USNRC, 1977). The internal dose conversion factors were obtained from DOE/EH-0071 (USDOE, 1988).

The results of the dose estimates for each food type are reported in the following sections. The four-year trend in total EDE from consumption of all the sampled food products is plotted in Figure 4-6. All of the calculated doses are well below both the EPA and DOE limits discussed in the previous sections.

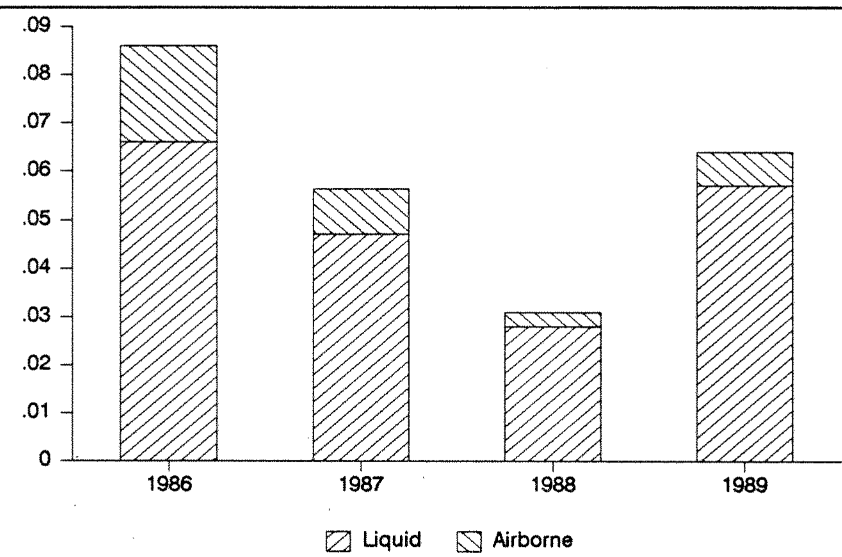


Figure 4-5

Collective dose equivalent (person-rem) from liquid and airborne effluents to the population residing within 80 km of the West Valley Demonstration Project.

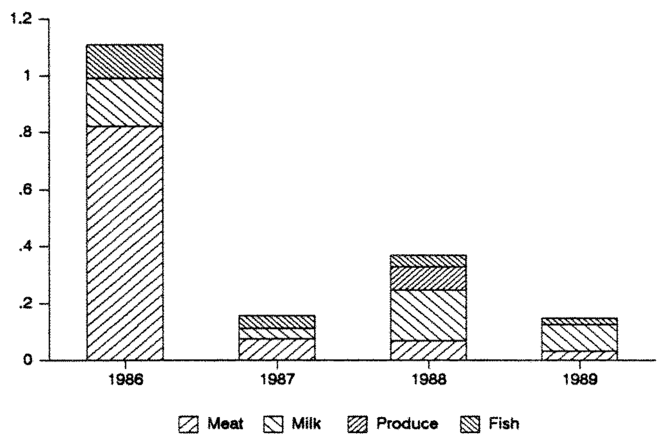


Figure 4-6

Maximum effective dose equivalent (mrem) to an individual from consumption of foods produced near the West Valley Demonstration Project.

4.5.1 Milk

Milk samples were collected from various nearby dairy farms throughout 1989. Control samples were collected from farms 25-30 km (15-20 miles) to the south and north of the WVDP. As reported in Table C-3.1, milk samples were measured for tritium, strontium-90, iodine-129, cesium-134, and cesium-137. Only tritium and strontium-90 were found above minimum detectable concentration (MDC) levels in near-site samples. To obtain a conservative estimate, the average background concentration was subtracted from the near-site sample with the highest reported concentration. Based on an annual consumption rate of 310 liters (327 quarts), the maximum effective dose equivalent from drinking this milk was estimated to be 0.092 mrem (0.00092 mSv). The highest organ dose equivalent to bone surfaces was estimated to be 1.1 mrem (0.011 mSv).

4.5.2 Beef

Near-site and control samples of locally raised beef were collected during middle and late 1989. As reported in Table C-3.2, these samples were measured for strontium-90, cesium-134, cesium-137, and potassium-40 concentrations. Samples are analyzed for potassium-40 because it provides a built-in calibration spike from a natural isotope of potassium not released in Project effluents. Only strontium-90 was detected above minimum detectable concentration levels in near-site samples, with the highest excess concentration reported in beef sampled during late 1989. Based on an annual consumption rate of 110 kg (242 lb), the maximum effective dose equivalent from eating this meat was estimated to be 0.033 mrem(0.00033 mSv). The highest organ dose equivalent to bone surfaces was estimated to be 0.41 mrem (0.0041 mSv).

4.5.3 Venison

Meat samples from three near-site and three control deer were collected in the last months of 1989. As reported in Table C-3.2, these samples were measured for strontium-90, cesium-134, cesium-137, and potassium-40 concentrations. Strontium-90 and cesium-137 were detected above minimum detectable concentration levels; however, average concentrations in background specimens were slightly higher than average concentrations in near-site specimens.

4.5.4 Produce (Beans, Tomatoes, and Corn)

Near-site and control samples of beans, tomatoes, and corn were collected in 1989. As reported in Table C-3.3, these samples were measured for tritium, strontium-90, potassium-40, cobalt-60 and cesium-137 concentrations. In all cases either the radionuclides were below MDC levels, or no statistically significant differences were found between near-site and control specimens.

4.5.5 Fish

Fish were caught in the second and third quarters of 1989 in Cattaraugus Creek upstream (control samples) and downstream (above and below the Springville dam) of the site. As reported in Table C-3.4, samples of fish flesh were measured for strontium-90, cesium-134 and cesium-137 concentrations. Only strontium-90 was detected above MDC levels, with the highest excess concentration reported in fish caught during the second quarter upstream of the Springville dam. Based on an annual consumption rate of 21 kg (46 lb), the maximum effective DE from eating this fish was estimated to be 0.023 mrem (0.00023 mSv). This compares fairly well with the 0.051 mrem (0.00051 mSv) estimated using the LADTAP II liquid effluent dispersion code. The highest organ DE (to bone surfaces) was estimated to be 0.29 mrem 0.0029 mSv).

4.6 Statistical Analysis Of Air Sampler Data

Environmental air samplers that measure gross alpha, gross beta, strontium-90, and cesium-137 concentrations are located near the site and at background locations. (See Tables C-2.12 through C-2. 20). To see if any measurable increases in airborne radionuclide concentrations could be detected in the air sampler data, a simple one-way analysis of variance (ANOVA) statistical test was performed. At the 99% confidence level only the Springville sampler showed statistically significant differences from the other sampler data. This difference was attributed to a faulty gas meter which has since been replaced. The Thomas Corners Road sampler, located between the site and the Springville sampler, showed no difference from background samplers. Concentrations measured at the Springville sampler since the repair date have returned to historically normal levels. Based on results drawn from the dispersion models, average concentrations of radionuclides contributed by Project airborne effluents would be five orders of magnitude below the measured background levels at the sampler locations. Such small increments are impossible to detect within the variability of background radionuclide concentrations in air.

4.7 Conclusions

In summary, the dose assessment shows that during 1989 the West Valley Demonstration Project was in compliance with all applicable emission standards and dose limits. The doses to the public estimated from effluent dispersion models and radionuclide concentrations in food samples were well below these limits, resulting in no measurable effects on the public's health.